A 1.3 GHz 100 kW Ultra-high Efficiency Klystron

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Abstract: *Calabazas Creek Research, Inc. is developing a high efficiency, 1.3 GHz, 100 kW klystron for driving accelerators. A design with an efficiency of 79% has been realized and a device is being fabricated. Details of the design and available test results will be presented.*

Keywords: klystron; accelerator

Introduction

Because of their high gain, low phase noise and moderately high efficiency, klystrons are the primary RF source for accelerators. But, with the increasing size of accelerators, there is an urgent need for higher efficiency. New design methods for klystrons put forth by Guzilov 2014 [1] (BAC: Bunch, Align, Collect method) and Baikov [2] (COM: Core Oscillation Method) offer efficiencies as high as 90%. These efficiencies are obtained by improving electron bunching through longer-spaced cavities or more complex cavity arrangements in the COM and BAC methods, respectively. Calabazas Creek Research Inc. used the COM method to produce a design for a 1.3 GHz, 100 kW CW klystron with an efficiency of 79%.

Design

A detailed examination was made of designs using the two approaches. While the efficiency achieved with the BAC approach was higher than that with COM, more cavities were required. For the most promising designs, 13 cavities were required using the BAC approach, while only 7 were required with COM. Although the COM device was longer, the cost of the BAC device was expected to be significantly higher. Since the efficiencies were similar, the COM approach was chosen.

The design was achieved using three different codes with increasing complexity and run times. The program initially used the 1D code AJDISK because it executed in about a minute and allowed rapid identification of promising configurations. Considerable optimization was done in conjunction with AJDISK using a code developed by one of the authors (A. Jensen). This was followed by the 2 ½ D code TESLA, which includes the magnetic field and calculates beam trajectories. Results were confirmed using the 2 ½ D, PIC code MAGIC 2D, which includes all the relevant physics.

The parameters of the final design are shown in Table 1.

Table 1. Operating parameters of the CCR klystron, as calculated using TESLA.

Power	104.4 kW
Frequency	1.3 GHz
Voltage	53.5 kV
Current	2.46 A
Efficiency	79.4%
Number of cavities	7

The cavity locations and magnetic field are shown in Figure 1.

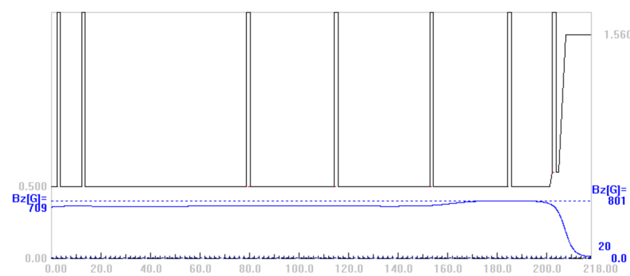

Figure 1. Cavity locations and magnetic field.

Results of the simulations using the three codes are shown in Figures 2 and 3.

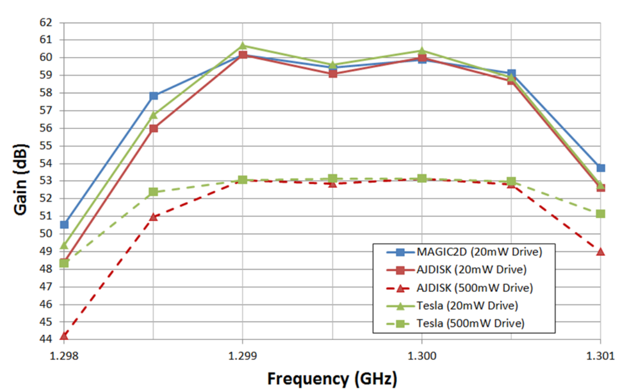

Figure 2. Gain versus frequency for the 1.3 GHz, 100 kW high efficiency klystron.

The TESLA and MAGIC simulations used beam trajectory data from the 2½ D code TRAK. The gun designed is shown in Figure 4. The continuation of the trajectories as calculated in TESLA is shown in Figure 5.

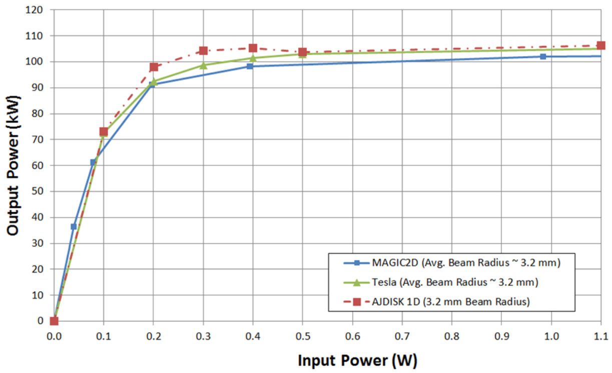

Figure 3. Saturated power for the klystron.

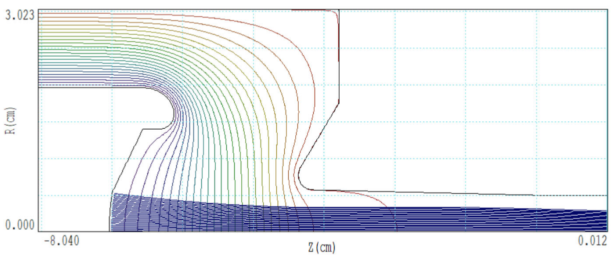

Figure 4. TRAK simulation of the electron gun.

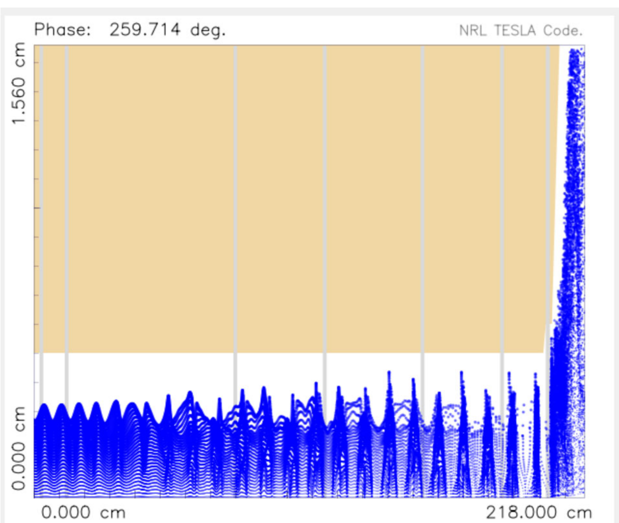

Figure 5. Trajectories, starting with the beam determined by TRAK, from TESLA.

The beam normalized velocity, β is shown in Figure 6. A small portion of the beam has negative β near the gap of the output cavity, but no electrons were reflected. This was confirmed with the code MAGIC. MAGIC also confirmed that the klystron will not self-oscillate.

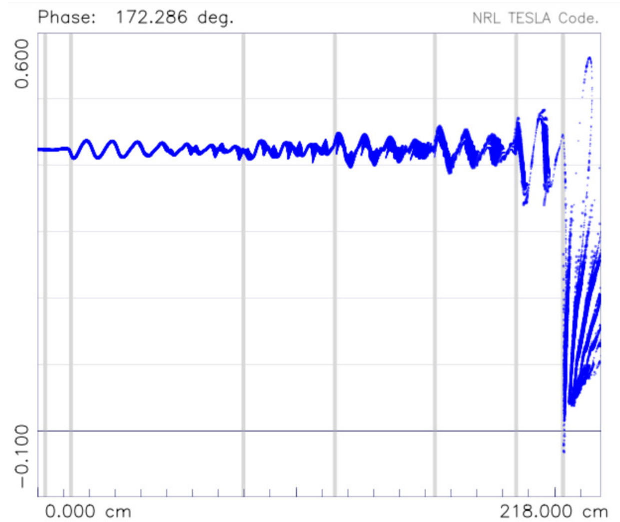

Figure 6. Normalized beam velocity, β, as a function of axial position. A small portion of the beam has negative β near the gap of the output cavity, but no electrons are reflected.

The collector with the spent beam from TESLA is shown in Figure 7. The peak power density is 181 W/cm^2, well under the nominal maximum of 300 W/cm^2.

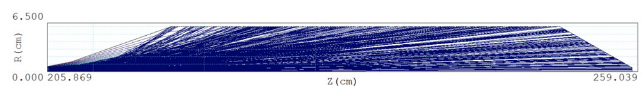

Figure 7. Collector with the spent beam from TESLA.

Fabrication and Testing

The klystron is being fabricated and testing is expected to start early in 2021.

Acknowledgements

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Staff from Communications and Power Industries, LLC, have provided valuable reviews of the CCR design. Plans call for testing using CPI facilities.

References

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